

Biorefinery Optimization Tool — Development and Validation

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1. Initial Premise

- Biorefinery concept proposed as means of improving economics of next-generation technologies
- Use various biomass feedstock options
- Produce a mix of fuels, power, and high-value co-products
- Must optimize feedstock and product mix
- Biorefinery similar to petroleum refinery

Objective

Develop Excel-based software to optimize selection of feedstocks, products, and process configurations for conceptual biorefineries

- Use VBA Macros and Solver Add-In

4. LP Formulation

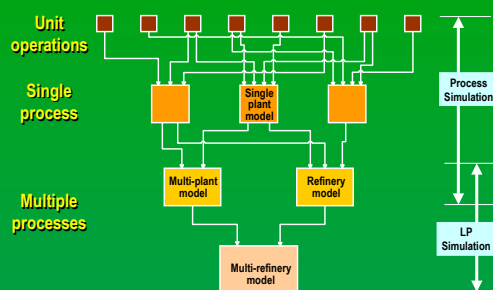
$$\begin{aligned} ax_1 - bx_2 + cx_3 + dx_5 &= A \\ -ex_1 - fx_2 + gx_4 - hx_5 &\leq B \\ ix_1 - jx_3 + kx_4 &\geq C \end{aligned}$$

LP Tableau

x_1	x_2	x_3	x_4	x_5	s_1	s_2	RHS
+a	-b	+c		+d			A
-e	-f		+g	-h	+1		B
+i		-j	+k			-1	C
+m	+n		-o	-p			Obj.

S_1 and S_2 are slack variables RHS , Right Hand Side $Obj.$, Value of objective function

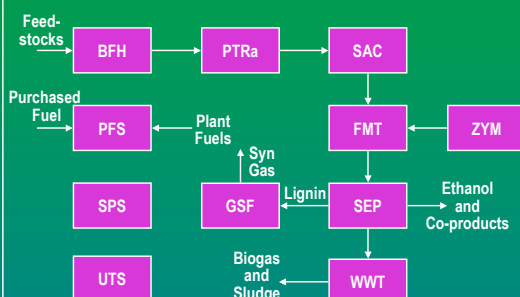
2. Modeling Hierarchy



3. Comparison of Approaches

Process Simulation	LP and NLP Simulation
Model driven	Data driven
Relies on theories	Relies on mathematics
Engineering	Economics
Iterative solution	Equation oriented
Case studies	True optimization

5. Biorefinery Block Flow Diagram

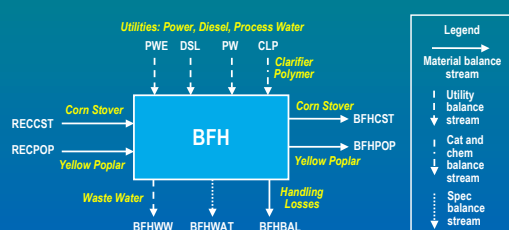


6. Worksheets in BioRefine.xls

SOLV	Setup and solver	SSEP	Co-product separations
ECON	Economics	SGSF	Gasification
PURC	Purchases	SZYM	Enzyme production
SALE	Product sales	SWWT	Waste water treatment
SBFH	Biomass feed handling	SPFS	Plant fuel system
SPTR	Pretreatment	SUTS	Other utility systems
SSAC	Saccharification	SSPS	Steam and power
SFMT	Fermentation		

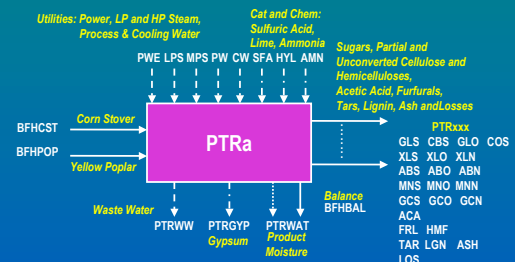
7. SBFH — Biomass Feed Handling

Receiving, storage, washing and sizing of biomass feedstocks



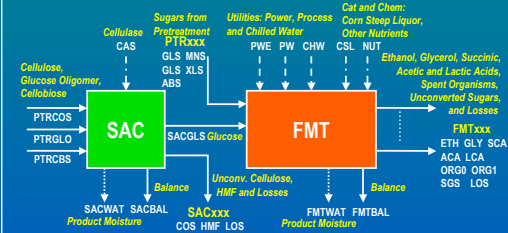
8. SPTRa — Biomass Feed Pretreatment

Mild/severe acid hydrolysis pretreatment of washed and sized biomass feedstocks



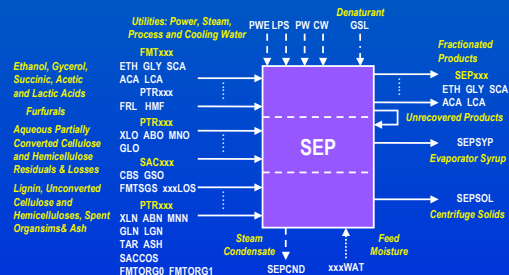
9. SSAC — Cellulose Saccharification SFMT — Sugar Fermentation

Simultaneous enzymatic saccharification and microbial fermentations to ethanol and lactic acid

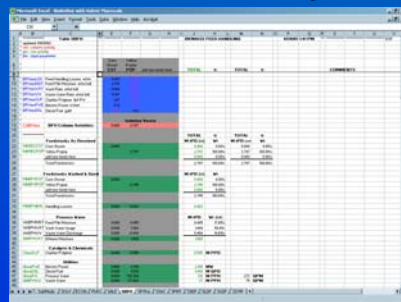


10. SEEP — Co-Product Separation

Recovery and purification of various products from hydrolysis and fermentation



11. SubModel Template



12. SubModel Template



13. Potential BioRefine.xls Studies

- Feedstocks
 - Corn Stover
 - Poplar
- Co-Products
 - Ethanol
 - Glycerol
 - Succinic Acid
 - Acetic Acid
 - Lactic Acid
 - Furfural
 - HMF
- Power Generation
 - CFBC with ST
 - GT and ST CC
- Other Products
 - Power
 - Waste Heat (steam)
 - Boiler Fuel
- Mild and Severe Hydrolysis
- Sugar Fermentation
 - Ethanol
 - Lactic Acid

14. Project Status

- Spreadsheet developed to optimize selection of feedstocks, products, and process configurations for conceptual biorefineries
 - Prototype delivered
- Further software development
 - User interface to improve ease of use
 - Automatic Solver setup
- Further verification of assumptions, structure, and data
- Biorefinery scenarios

15. Acknowledgement



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